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HIGH INTENSITY SOLAR SIMULATION TEST FOR STRUCTURE PARTS AND EXPERIMENTS FOR THE HELIOS SOLAR PROBE

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ABSTRACT

The entire HELIOS solar probe cannot be tested with the intensity of 16 solar constants corresponding to 0.25 AU mission. Therefore critical parts of the solar probe have been tested in an especially built sc lar simulation test facility in the Space Simulation Institute of the DFVLR. The requirements of the structure and experiment engineers and physicists were changed from one test specimen to the other. After a brief description of the solar simulation system, the different requirements and their technical solution will be discussed. This includes the possibilities of flash illumination corresponding to the spin rate of HELIOS, as well as the background for the test article.

1. INTRODUCTION

The mission of solar probe HELIOS leads to an approach to the Sun that up to now was never reached by a flight object launched from the Earth. By this fact requirements of the thermal household as well as of structural parts of the probe and experiments must be met which were so far unknown in space research. These requirements necessitate a detailed examination of critical parts in tests by a very close adaptation to the real conditions. Increased consideration must in this connection be given to the subsystem tests.

In order to be able to conduct such subsystem tests, the German Ministry for Science and Technology assigned the task to the Space Simulation Institute of the DFVLR to develop a High Intensity Solar Simulation unit, the main components of which are briefly described in the following. [1]

2. Brief description of plant

2.1. High Intensity Solar Simulator

In the left half of picture 1 the opened solar simulator is visible. We have to deal with an on-axis system with divergent beam. As a light source we use a water cooled 20 KW

Xenon lamp the main mirror of which reflects the light vertically downwards. A diverting mirror under 45° versus the horizontal line directs the beam into the exit window of the solar simulator. This exit window consists of a lenticular lens system comprising 2 x 19 lenses. Between the folding mirror and the lenticular lens system an attenuator and a douser are fixed with the aid of which each desired irradiance can be adjusted continuously between 0.8 and 16 solar constants. The spectral adaptation to the Johnson curve is carried out by an optical filter between the two lens systems (system manufacturer: Messrs. Spectrolab).

The radiation cone has the shape of a hexagon with an inner circle of 300 mm diameter in the so-called reference plane, that is the area which is situated vertically to the radiation axis in the axis of the motion gear, which will be described later. The deviation of the local intensity from the mean value of the mentioned area is smaller than ± 5 %, the time constancy of the irradiance is better than ± 1.5 %.

The virtual light source for determining the irradiance in the direction of the radiation is placed at a distance of 1835 mm in front of the reference plane. (Picture 2)

2.2. Vacuum and Shroud System

As vacuum chamber a plant is used which was originally constructed for a carbon arc solar simulator with 1 SC and in which certain modification had been carried out with respect to the shroud. The usable volume in the interior of the shroud has a diameter of 900 mm and is 1400 mm long. The plant can be baked out up to 200 °C.
The vacuum system with an oil diffusion pump has a capacity of 2000 l/sec. The ultimate vacuum of the plant in the CDE-test is lower than 10^{-8} torr, measured with an open ionisation manometer tube inside the shroud.

2.3. Motion Gear and Data Acquisition Plant

As already mentioned before, there is a one-axis motion gear in the reference area, the rotation axis of which is vertical to the radiation axis of the solar simulator. With the aid of this motion gear, rotations of the test specimen with 0 - 10 rpm can be carried out. The transmission of the measurement values is completed via a harness which reduces the angle of rotation of the test specimen to 720°. The registration and evaluation of the data is conducted - depending on the requirements - by one of the data acquisition systems which are available in the Institute, which, however, are not described in detail in this paper.

2.4. Use of the 2.5 m Thermal Vacuum Chamber for High Intensity Tests

For completion purposes it must be mentioned that besides the high intensity test facility, the Institute includes also a space simulation facility, the cold wall of which has a diameter of 2.5 m and its cylindrical length is 5 m. As solar simulator a divergent system comprising ten 6.5 KW Xenon lamps is in use. All 10 radiation cones enter through a window of 500 mm diameter into the chamber. The complete cover of the cones is reached in the reference area with 1300 mm diameter. A partial overlapping of the cones is available in front of the reference area. By approaching the test specimen to the entrance window it is thus possible to produce for instance 11 solar constants on a diameter of 300 mm at a uniformity of better than $\pm$ 5 %. This facility was also used for thermal tests at the start of the HELIOS project and for test specimens with too large dimensions.

3. Conducting of the Test

3.1. Types of Test

With reference to the test specimen, 4 types of tests can be distinguished:

- IR-heater calibration
- Thermal balance tests
- Components qualification tests
- Experiment sensor tests

3.1.1. IR-Heater Calibration Tests

For verifying the thermal household of the total system, IR-tests are conducted according to the canister method. For this purpose the probe's surfaces which are exposed to solar radiation are surrounded by a canister which has IR radiators. These IR radiators convey the same energy to the probe which it receives during rotation on its orbit from the Sun. At the experiment openings, however, difficulties arise, as the surfaces do not more correspond to the closed shape of the main body. For this reason special heaters must be mounted at these places which need separate calibration. For this purpose the experiment opening is first loaded by various irradiances. The resulting temperature at various points of the opening or of the experiment are then measured. Thereupon the IR heater is mounted in front of the area and the heating load is found which is necessary to obtain the same temperature as before with simulated solar radiation and identical background.

3.1.2. Thermal Balance Test

The temperature resulting from heat conductance and radiation exchange is found by this conventional test method. Usually the thermal household of the experiment is controlled within the solar simulation tests with the thermal model of the spacecraft. As high intensity solar simulation tests of the entire spacecraft cannot be carried out as described before, in this case the thermal household of the experiment must be tested for each experiment separately. The background of the experiment must be simulated by an especially designed temperature controlled box. Our experiences have proved that a good radiation exchange of the box with the shroud of the simulation facility at simultaneous counter heating with soldered on electrical heaters leads to easily ontrollable results.

As the solar simulator is constructed as a divergent system, care must be taken when assembling the experiment that the rotation axis of the motion gear passes through the area to be tested, so that the maximum intensity is not greatly exceeded during the rotation of the test specimen.

The sides of the boom experiments E2A and E4A which are constantly turned away from the Sun, are equipped with radiators which serve as reflection sides. During the first tests with these experiments it had been tried out to avoid a lateral incidence of the divergent ray in the radiator areas by mounting screens. These tests, however, did not give the expected result. On suggestion of our Institute thereupon LN_2-cooled screens adapted in their shape to the test specimen, were built in the chamber, which screens ensure a complete shadowing of the radiator areas without making special changes for the test.

3.1.3. Components Qualification and Experiment Sensor Tests

The purpose of these tests is to investigate the influences of flashes of high intensity on active components, as for instance solar cells, experiment windows and open sensors; these flashes are caused by the spin rate of the solar probe. By simulation of the thermal level, the background temperature of the component to be investigated is reproduced by suitable measures. Also for this purpose the method of radiation exchange with the shroud at simultaneous counter heating of the mounting support, as previously described, has given satisfactory results. The actual physical influence by the light impulses is superimposed by the processes resulting from the equilibrium temperature of the component. (Picture 3)

Only after completion of the plant, the experimentors expressed their request for simulating the light impulses. For dimension reasons it was not possible to integrate suitable devices between the solar simulator and the vacuum chamber. A corresponding mounting in the solar simulator itself had to be excluded as it would have interfered with the internal GN_2-cooling. The only solution of the problem was therefore the mounting of shutters inside the vacuum chamber. To achieve this, two methods could be applied which were both investigated by experiments.

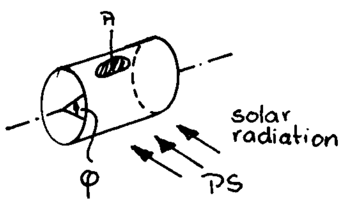
- Pendulum with shutter, cycle operation via electromagnet;
- rotating sector disc.

A third method using a rotating "Venetian blind" had to be dropped, as a reduction of the intensity would have resulted when the Venetian blind was open from about 3 to 5 %. For reasons of operation security the rotating disc was preferred to the pendulum method.

For the use of the sector disc the following marginal conditions are valid: [2]

1. The energy radiated to the experiment opening corresponds to the total energy of each revolution of the solar probe.

2. The maximum radiated intensity corresponds to the intensity in the perihelion, or the distance to be examined resp.



$$\dot{Q}_{orb} = \frac{PSA \int_{-\pi/2}^{+\pi/2} \cos\varphi \, d\varphi}{\int_0^{2\pi} d\varphi} = \frac{PSA}{\pi}$$

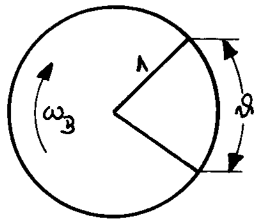
$\varphi = \omega t$

$$\dot{Q}_{orb} = \dot{Q}_{sim} = T \frac{PSA}{\pi} = t \, PSA$$

consequently:

(1) $$\frac{T}{t} = \pi$$

with
$$T = \frac{2\pi}{\omega_B}$$



and
$$t = \frac{\vartheta}{\omega_B}$$

follows

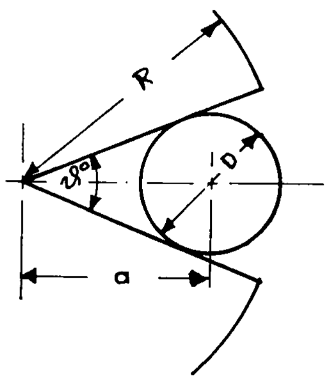
(2) $$\frac{T}{t} = \frac{2\pi}{\vartheta}$$

with (2) in (1)
$$\hat{\vartheta} = 2 \mathrel{\hat{=}} 114.8^{\circ}$$

For the dimension of the sector disc, under the condition that the total area of the experiment has to be irradiated, the following results:

$$R = a + \frac{D}{2}$$

with $\sin\frac{\vartheta}{2} = \frac{D}{2a}$



$$D = \frac{2R}{1 + \frac{1}{\sin\frac{\vartheta}{2}}}$$

$$= \frac{2R}{1 + \frac{1}{\sin\frac{\hat{\vartheta}}{4\pi}360^{\circ}}}$$

with $\hat{\vartheta} = 2$

$$D \approx 0.9\,R$$

In conjunction with the usable diameter of the shroud, these conditions cause a limitation of the test specimen for light impulse measurements to maximum 270 mm diameter, which, however, cannot be utilized fully for construction reasons.

With this test method various tests are conducted by the Institute. As an example, the following tests are mentioned:
tests to prove the stability of parylen foils of 1.3 µ thickness which are vaporized on both sides by 0.1 µ Al; the output of solar cells, the background noise of semiconductor detectors, and similar tests.

SUMMARY

By its extreme requirements - especially with respect to thermal conditions - solar probe HELIOS demands efforts of the engineers involved in its development, as no other space experiment before has ever asked for. The scientists and technicians responsible for ground tests must find ways which harmonize technical requirements and commercial possibilities.

Some examples out of the various test tasks demonstrate which requirements have to be met, and which solutions our Institute has found. We hope to have thus contributed somewhat to the development of space simulation.

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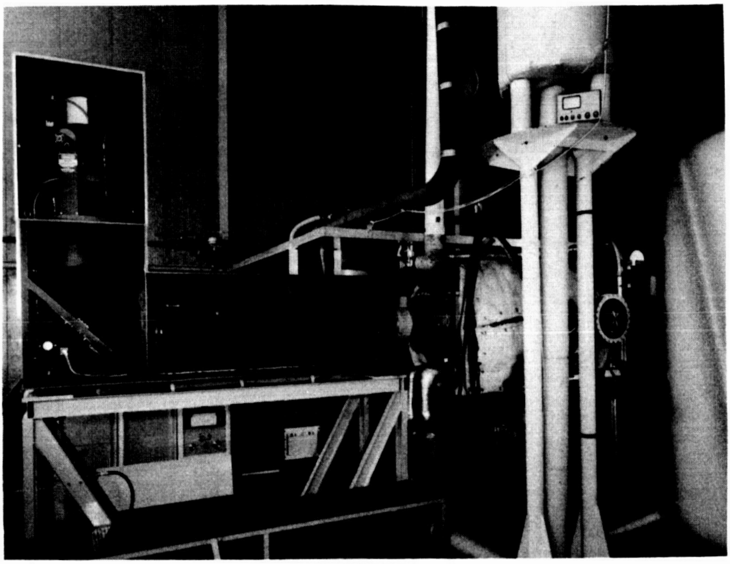
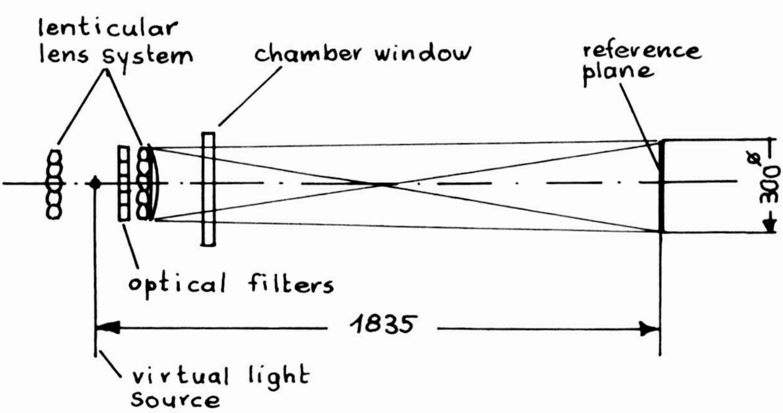
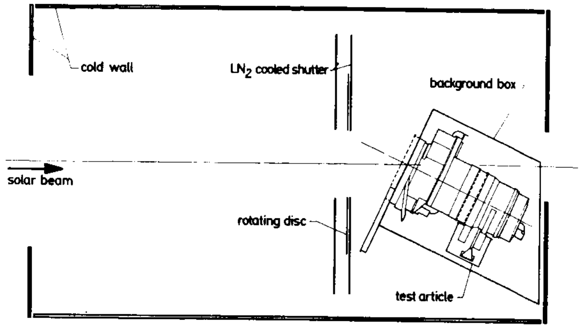


Picture 1: Overall view of the high intensity solar simulation test facility (the housing of the solar simulator is open)



Picture 2: Beam of the solar simulator between lenticular lens system and reference plane



Picture 3: Typical setup for test of an experiment for the HELIOS solar probe with light impulses (experiment EOB)